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EMERGENCY AND ESCAPE PROCEDURES

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EMERGENCY AND ESCAPE PROCEDURES

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and
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Presented at the
Physiological Training Officer Symposium
School of Aviation Medicine
Brooks Air Force Base, Texas
13-17 June 1960

INTRODUCTION

In the light of our mutual interest in achievements aeronautical, we have watched with some amazement the progress of human factors in aviation during the last short decade-and-a-half. The triply-corseted aircrew of the subsonic bomber is on the verge of emancipation as the Mach 3 weapon system offers an airliner cabin environment. Even the armor-clad full-pressure suit of the experimental space vehicle pilot is being superseded by one vastly more reliable and comfortable.

Paralleling these accomplishments and contributing to them is the advance in aircrew emergency and escape technology, which, despite the leaps in intra- and extra-atmospheric vehicle performance, is furnishing increased assurance of safety and survival.

In this discussion, it seems appropriate first to define one or two methods by which escape devices designed fifteen or more years ago, may be considerably improved. Second, the ejection seat-pressure suit combination of a research aircraft will be described, followed by a report concerning the encapsulated seat of a Mach 3 air vehicle. Last, there will be a brief examination of the aspects of escape from space vehicles.

SERVICE IMPROVEMENTS IN EMERGENCY SYSTEMS

Because automatic, timely deployment of the personnel recovery parachute in service depends upon punctual departure of the seat from the occupant after ejection, the installation of a device to achieve positive separation is of great benefit. The most effective method appears to be the ballistic take-up of webbing

which is normally sandwiched between the seat and occupant, Figure 1.

A second, economic improvement, with even more promise, is the replacement of existing seat ballistic catapults by rocket catapults by which post-ejection clearance of airplane structure at maximal airspeeds is assured, airstream-induced accelerations are decreased appreciably, and, of greatest importance, a true low-altitude capability is made available. In conjunction with the seat-man separator and zero-delay recovery parachute release, the rocket catapult, substituted for the current M-3 or M-5 catapult, will allow safe ground-level ejection at 100 knots.

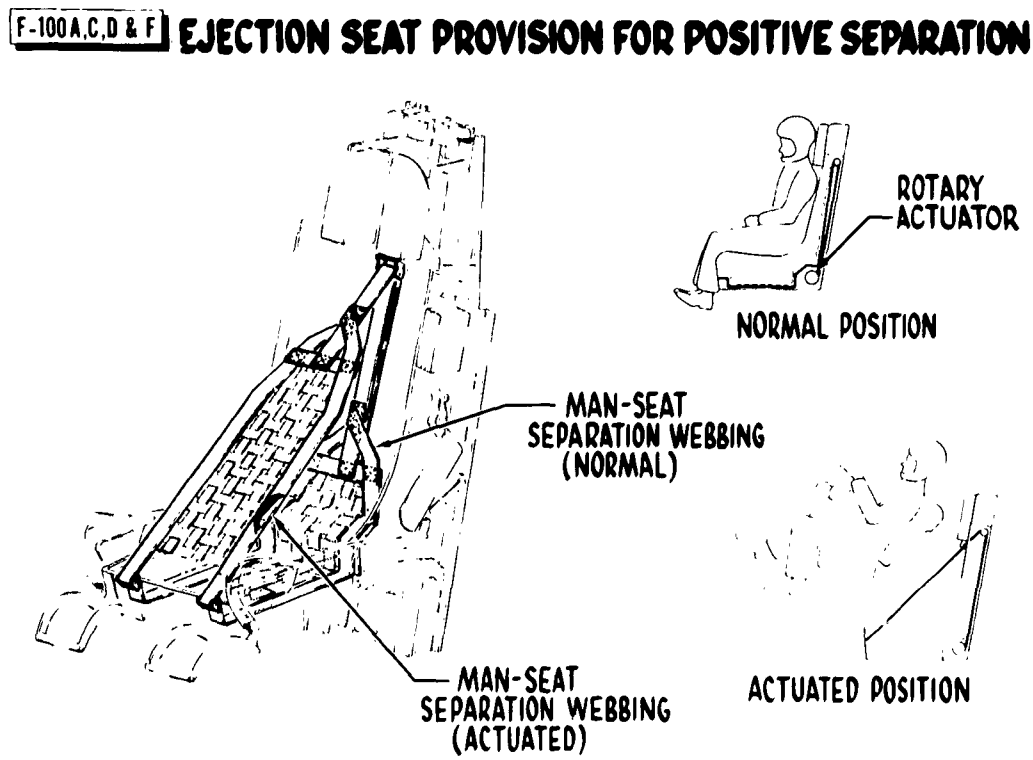
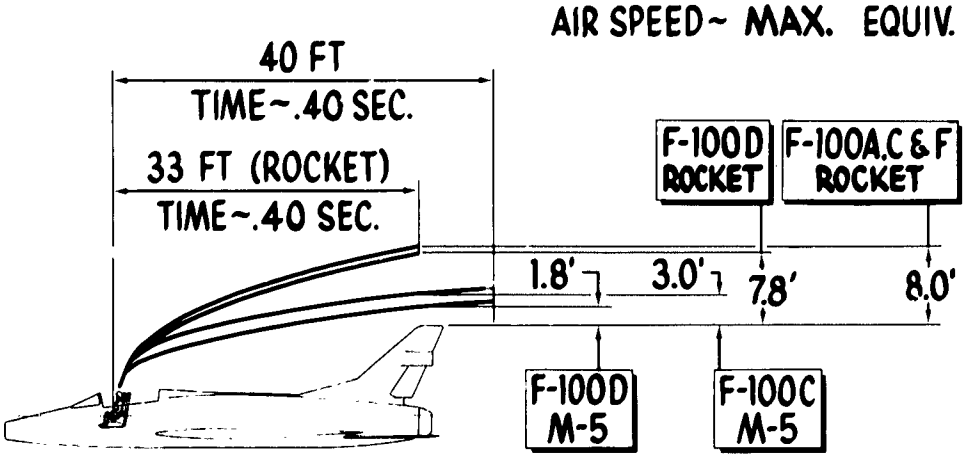


Figure 1

F-100

ROCKET CATAPULT VS M-5 CATAPULT COMPARISON



- LOW ALTITUDE ESCAPE
- REDUCED ACCELERATIONS
- INCREASED STRUCTURAL CLEARANCE
- GREATER STABILITY

Figure 2

F-100

ROCKET CATAPULT VS M-5 CATAPULT COMPARISON

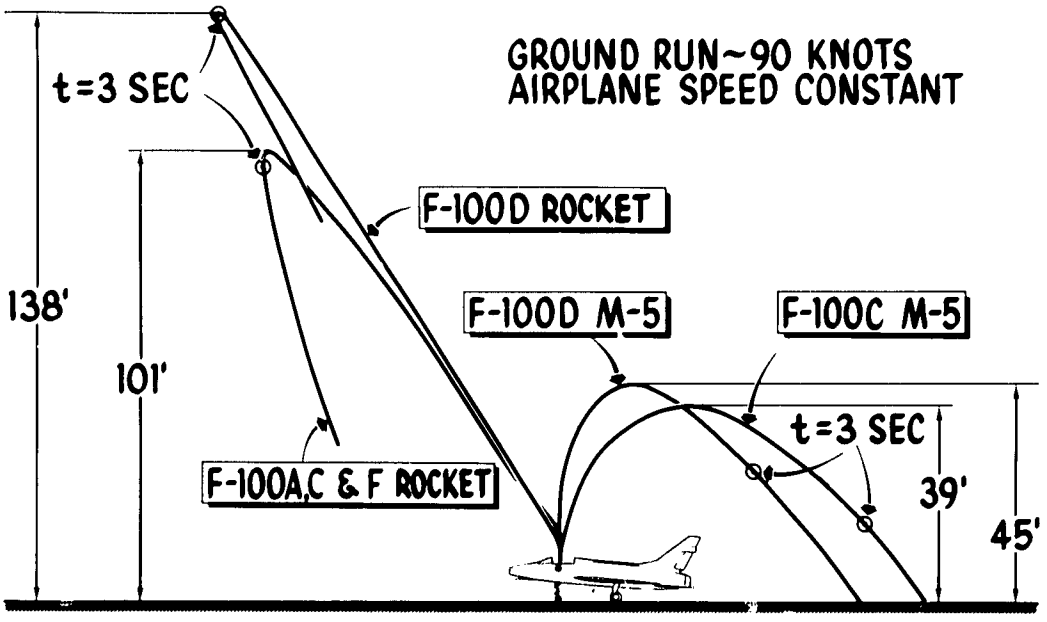


Figure 3

AEROSPACE EJECTION SEAT

In consideration of the basic requirement for a full-pressure suit, an upward ejection seat was selected for the X-15 research airplane after an extensive evaluation of the four types of escape systems shown in Figure 4. The escape envelope established for the system is bounded by Mach 4.0, a pressure altitude of 120,000 feet and an incompressible dynamic pressure of 1500 pounds per square foot, and was selected to encompass the 98% accident potential of the curve of Figure 5, assuming the pilot would remain with the air vehicle until severe flight conditions are relieved.

A paramount objective in the design of the seat was the proper placement of the pilot within the cockpit, particularly with reference to the eye and control stick positions. The ejection seat interior provides accommodations for a pilot dressed in the MC-3 pressure suit, which was developed to provide optimum protection without the inhibitions normally associated with pressure garments. This suit incorporates an integrated harness attached to the seat at the hips and shoulders, constituting the main component of the restraint subsystem which includes armrests with elbow guards, knee plates, foot restraint bars and the unique handgrips positioned over the lap upon ejection (Figure 6).

While being transported to launch altitude, the X-15 cockpit projects well forward of the carrier wing so as to permit unobstructed ejection (Figure 7).

To escape from the airplane, the pilot places his feet in the footrests and rotates the handgrips upward and inboard, thereby ejecting the canopy and seat in sequence. The rocket catapult provides zero-altitude escape at airspeeds

from 90 to 200 knots and at higher altitudes assures safe egress up to the maximum performance criterion.

Fins mounted on the sides of the seat and telescopic booms stowed beneath the seat deploy at the time of seat-air vehicle separation, providing aerodynamic stability. The pilot remains in the seat during free fall to 15,000 feet, or for 3 seconds if ejection occurs below this altitude. At this time, the restraint subsystem is released and the personnel recovery parachute, stowed in a container between the seat back and pilot, is deployed by jettison of the headrest, simultaneously discarding the seat.

In sled tests, Figure 8, the X-15 escape system has demonstrated safe egress at up to 690 knots equivalent airspeed. Only seven sled ejections were required to qualify the configuration, less than one-half the usual number.

The composite plot shown in Figure 9 illustrates the moderate accelerations associated with X-15 emergency escape. This important physiological parameter is an essential design feature.

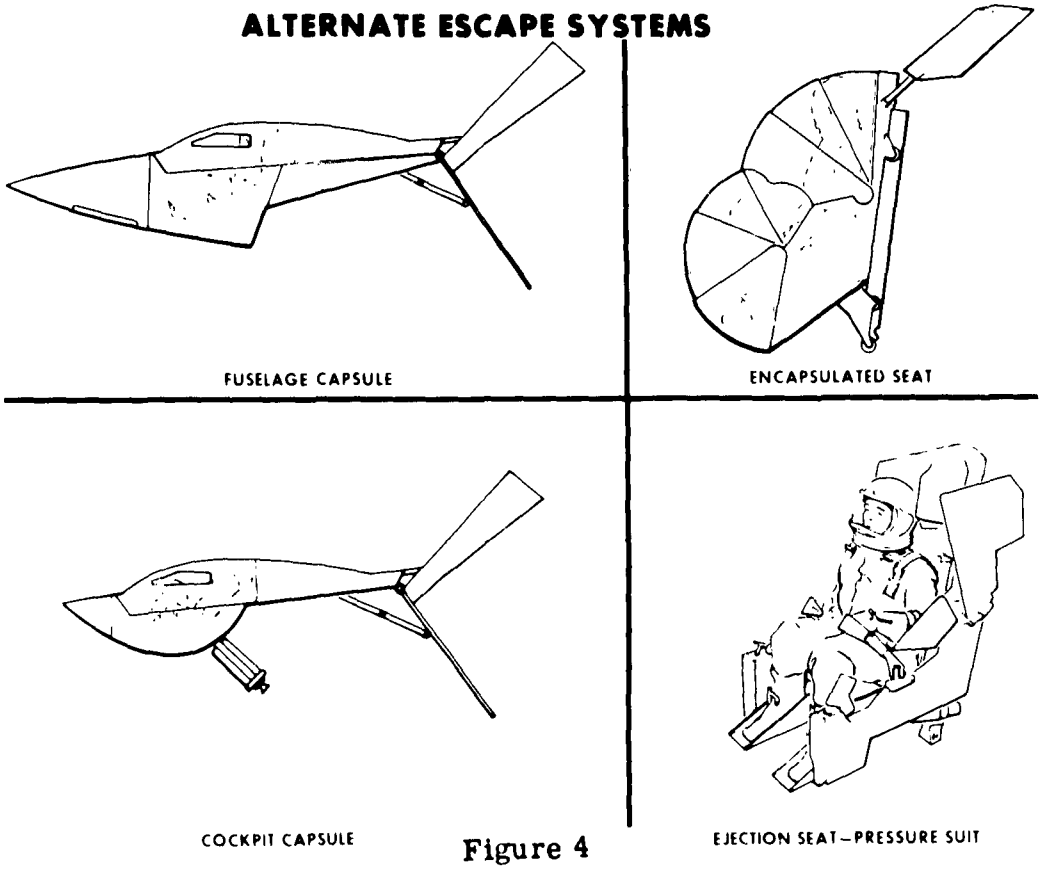


Figure 4

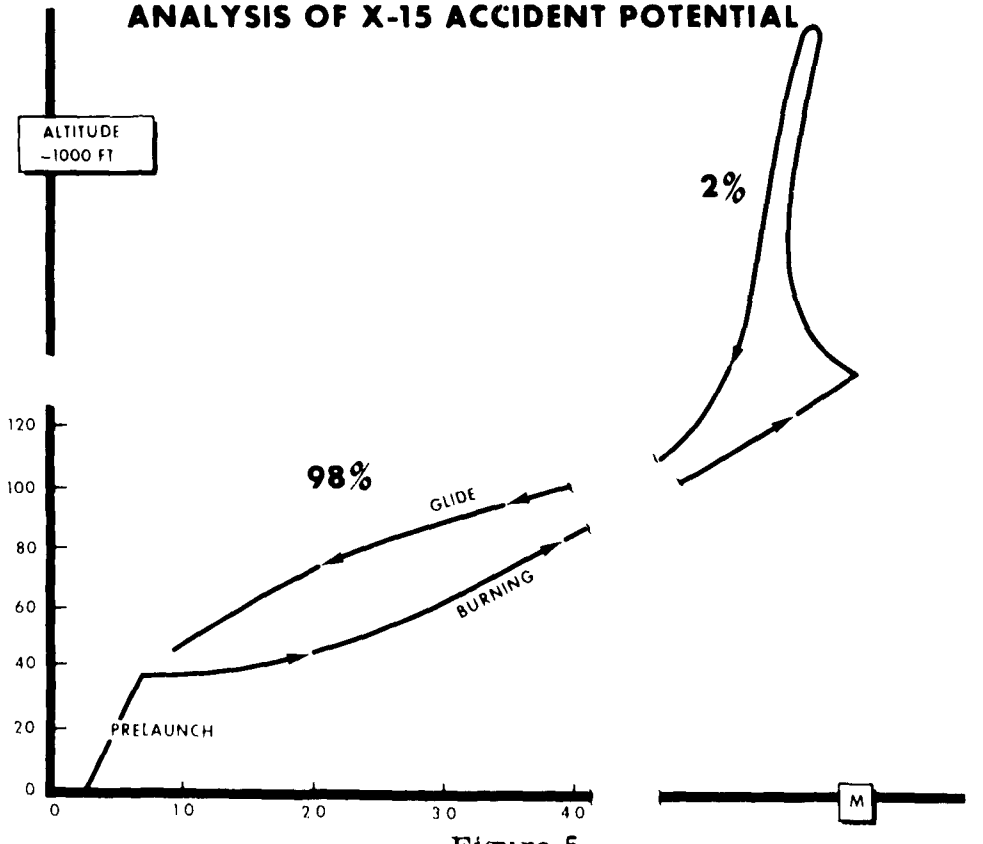


Figure 5

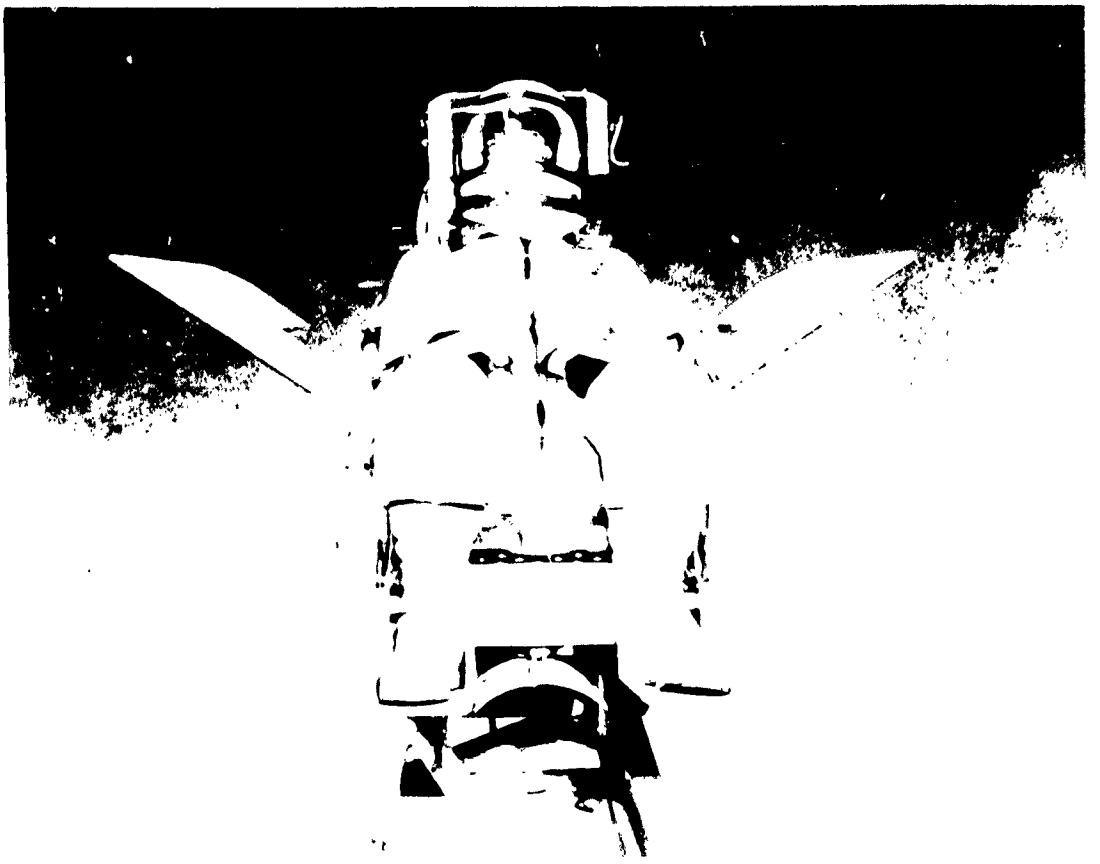


Figure 6
X-15 Ejection Seat

Figure 7
X-15 and Carrier

Figure 8

SEAT OCCUPANT ACCELERATIONS (C.G. 3-AXIS RESULTANT)

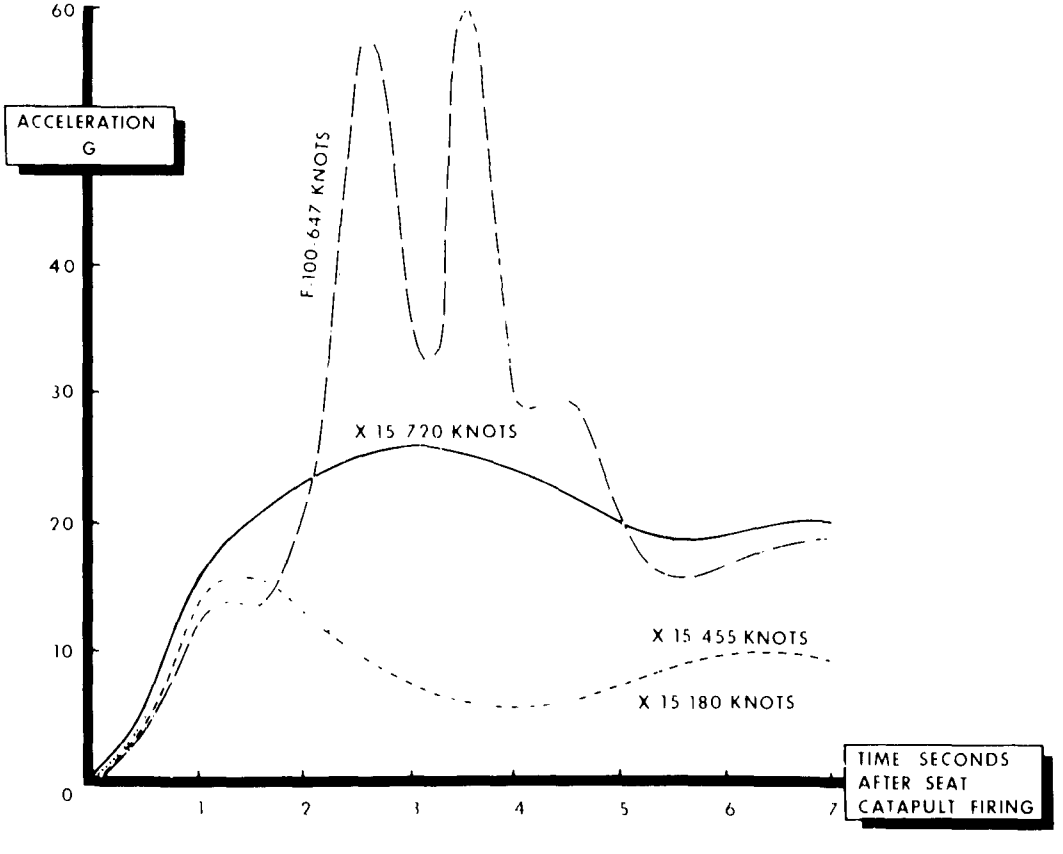


Figure 9

AEROSPACE ESCAPE CAPSULE

The encapsulated ejection seat of the B-70 weapon system, shown in test configuration by Figure 10, provides both shirtsleeve occupancy of the air vehicle in normal flight and immediate abandonment in emergency. Crew clothing is reduced to a flying suit and lightweight helmet (Figure 11), the capsule's functions eliminating the requirement for counter-pressure, ventilation and anti-exposure garments. The oxygen mask is relegated to a ready position on the crewman's chest.

The seat occupant, in normal flight, sits well forward of the capsule shell, with unrestricted mobility, vision and comfort. Actuation of either of two control levers ballistically retracts the seat and crewman into the shell, closes the clamshell doors from top and bottom, and pressurizes the capsule interior to an equivalent altitude close to sea level. From this condition, the pilot, monitoring his instrument panel through the capsule's center window, may control the air vehicle, or he may eject by pressing one of two triggers at his side. The retracting-enclosing sequence may be performed alternately by hand, and may be reversed at will to restore the crewman to his usual position in the cabin.

Ejection can be accomplished safely at all points within the performance envelope of the air vehicle. The catapult rocket produces a maximum of 17 "g" vertical acceleration to lift the capsule to 400 feet height at 90 knots and to clear the air vehicle's empennage by 100 feet at maximum airspeed. Medium and high speed aerodynamic stability is imparted to the capsule by long cylindrical

booms, Figure 10, while low speed and free-fall stability results from the addition of small parachutes to the boom ends, Figure 14. The booms are fully extended one-tenth second after ejection, the parachutes opening 1-1/2 seconds later.

If ejection occurs above 16,000 feet altitude, the main recovery parachute withholds deployment until the capsule descends to this altitude. Under all other circumstances, the parachute is released 2-1/2 seconds after ejection, passes through a two-second reefing stage and is fully open between six and nine seconds after ejection, depending upon air vehicle airspeed. To achieve maximum reliability, no force or airspeed sensing device is employed in the recovery parachute system, which has successfully completed a qualification series of 70 full-scale tests, Figures 12 and 13.

Simultaneously with main parachute activation, the ground landing impact attenuator, an inflated bladder, is extended from the bottom of the capsule. Acting as alighting gear, the attenuator and booms bring the capsule and occupant to rest (Figure 14) at a maximum acceleration of approximately 15 "g". In the water, the capsule is self-righting from all attitudes, with or without the supplementary flotation bladders attached to its sides. Fifty pounds of survival gear are provided.

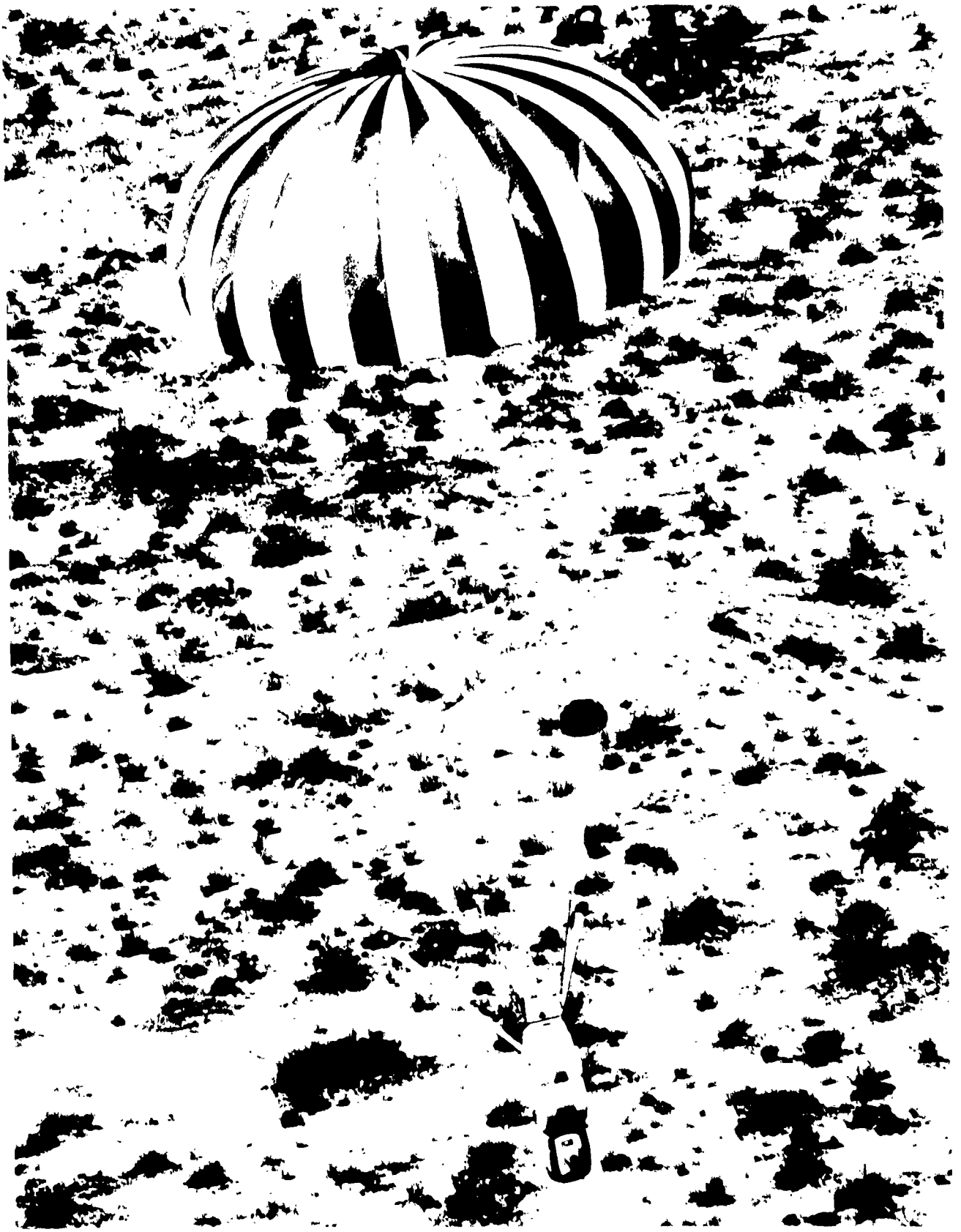


Figure 10
B-70 Escape Capsule

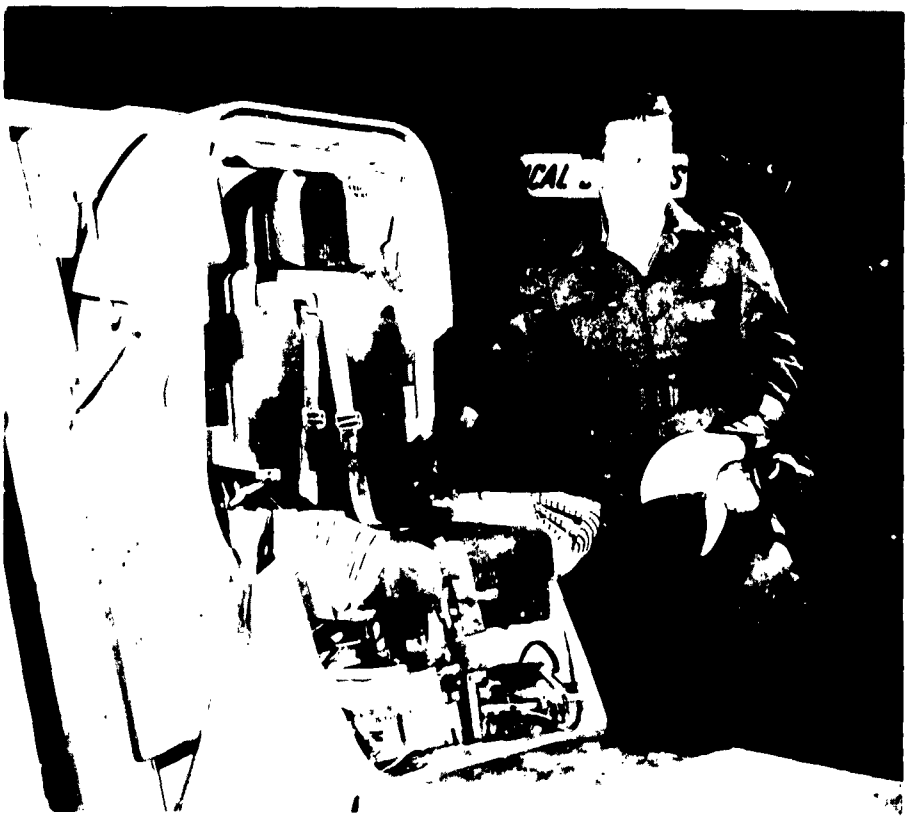


Figure 11
Capsule - Flight Configuration

Figure 12
Capsule Sled Ejection

Figure 13
Capsule Airdrop

Figure 14
Capsule After Touchdown

EMERGENCIES IN ORBITAL VEHICLES

The space vehicle, on the launching pad, is exposed to its rocket booster's combustible, toxic fuels, thus creating the initial hazard to the safety of the crew. After lift-off, the vehicle may attain very little altitude before plummeting back to earth, the mission aborted because of propulsion malfunctions (Figure 15). To counter these perils, the emergency must be detected by the vehicle crew or by the ground observer who must effect remedial action without delay.

In wingless configuration (Figure 16), the space craft itself is most readily employed as the escape unit. Auxiliary rockets are attached either to the rear of the vehicle or to an extension well in front; these rockets are canted to afford adequate lateral separation from the booster. In escape at very low altitude, the vehicle is projected to sufficient height, some 2500 feet, to ensure proper opening of the large main recovery parachute. The landing is softened by energy-absorbent devices.

Because the greater mass of the winged space vehicle will not permit rapid removal from the scene of emergency by auxiliary propulsion, it appears that the open ejection seat or encapsulated seat will provide the most reliable means of escape from this configuration (Figure 17). At least one existing rocket catapult possesses sufficient impulse to yield both the altitude and lateral displacement required here.

During boost phase, up to about 70,000 feet, circumstances surrounding escape are similar to those of intra-atmospheric craft, although we must make certain that the capacity of the emergency artificial environment system is compatible with the time which will be spent at very high altitude following escape at great vertical velocity. We must also take care not to produce excessive accelerations by superimposing escape "g" upon booster "g".

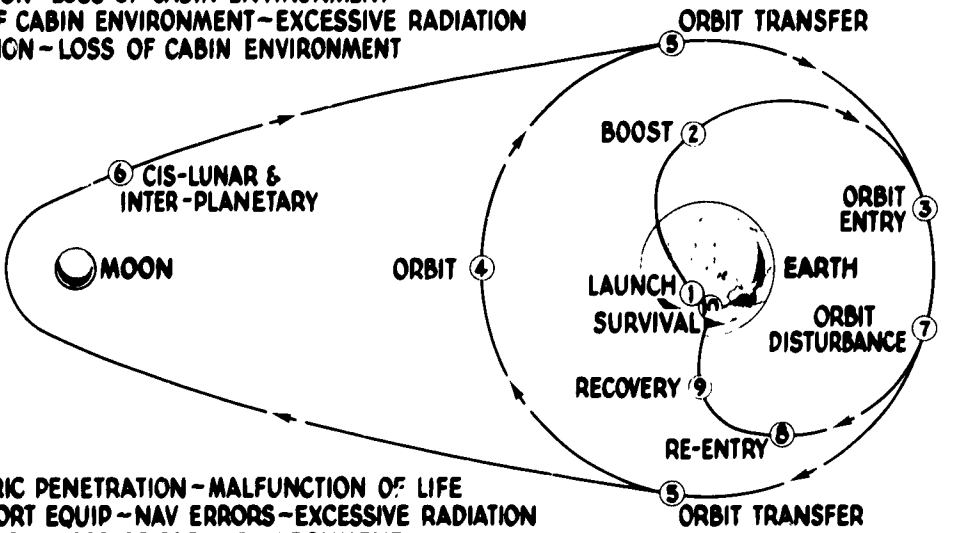
After passing the 70,000-foot mark with appreciable upward velocity, and during orbit and re-entry, parent vehicle integrity becomes the important survival factor. A separable escape unit for use in this phase is impractical in most instances because of the weight and complexity penalties associated with duplication in the escape device of the re-entry and environmental capacity of the primary craft. The wingless vehicle, returning to earth after the emergency, will be accompanied by its passengers to a parachute landing, while the crew of the winged craft may eject after flight performance is reduced to less than Mach 4.0 at 120,000 feet altitude.

Post-escape survival will be considerably enhanced by limiting orbital operations to the earth's equatorial belt (Figure 18), with its water/land ratio of four-to-one and average water temperature of 70°F.[3]

In projecting our discussion to lunar and interplanetary operations, we find a low possibility that the space vehicle will be irreparably damaged to the extent of forcing abandonment upon its crew. In the event evacuation is required, however, it has been suggested that a solution may be the application of more than one vehicle to a mission, providing mutual assistance capability.[1]

MISSION PHASE & HAZARDS

① EXPLOSION-CONTAMINATION BY FUEL-THRUST TERMINATION
② THRUST TERMINATION-EXPLOSION-GUIDANCE ERRORS
③ EXPLOSION-LOSS OF CABIN ENVIRONMENT
④ LOSS OF CABIN ENVIRONMENT-EXCESSIVE RADIATION
⑤ EXPLOSION-LOSS OF CABIN ENVIRONMENT



⑥ METEORIC PENETRATION-MALFUNCTION OF LIFE SUPPORT EQUIP-NAV ERRORS-EXCESSIVE RADIATION
⑦ EXPLOSION-LOSS OF CABIN ENVIRONMENT
⑧ AERODYNAMIC OVERHEAT-EXCESSIVE "G"-NO ATTITUDE CONTROL
⑨ PARACHUTE MALFUNCTION
⑩ INCAPACITATION-SEVERE CLIMATIC CONDITIONS-ABSENCE OF SUSTENANCE REQUIREMENTS

Figure 15

"OFF THE PAD" ESCAPE

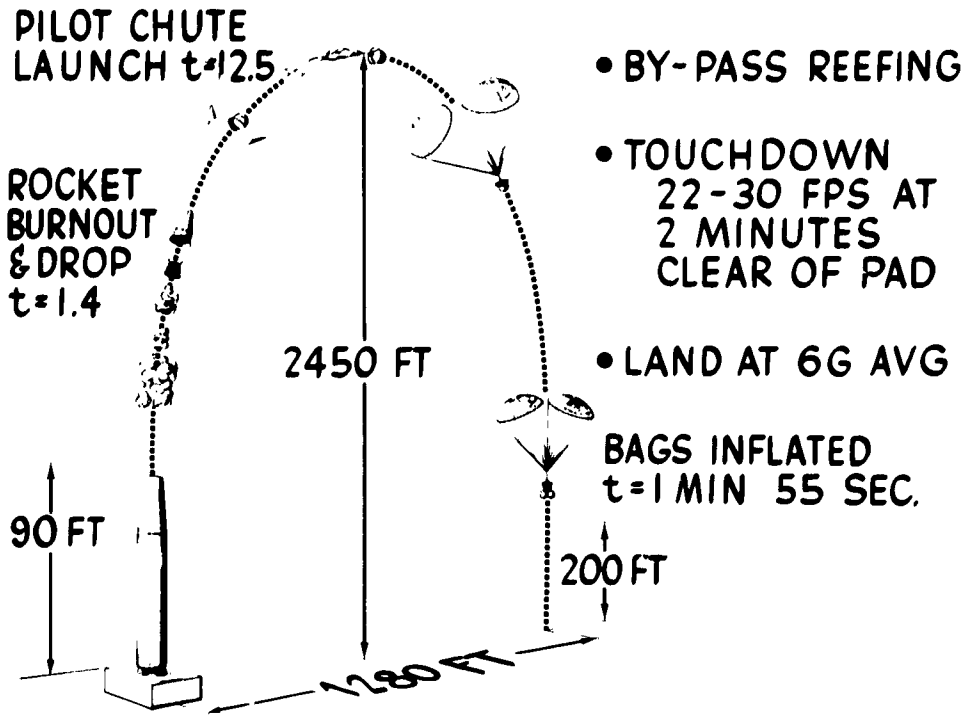

PILOT CHUTE LAUNCH t=12.5
ROCKET BURNOUT & DROP t=1.4
2450 FT
90 FT
1280 FT
200 FT
• BY-PASS REEFING
• TOUCHDOWN 22-30 FPS AT 2 MINUTES CLEAR OF PAD
• LAND AT 6G AVG
BAGS INFLATED t=1 MIN 55 SEC.

Figure 16

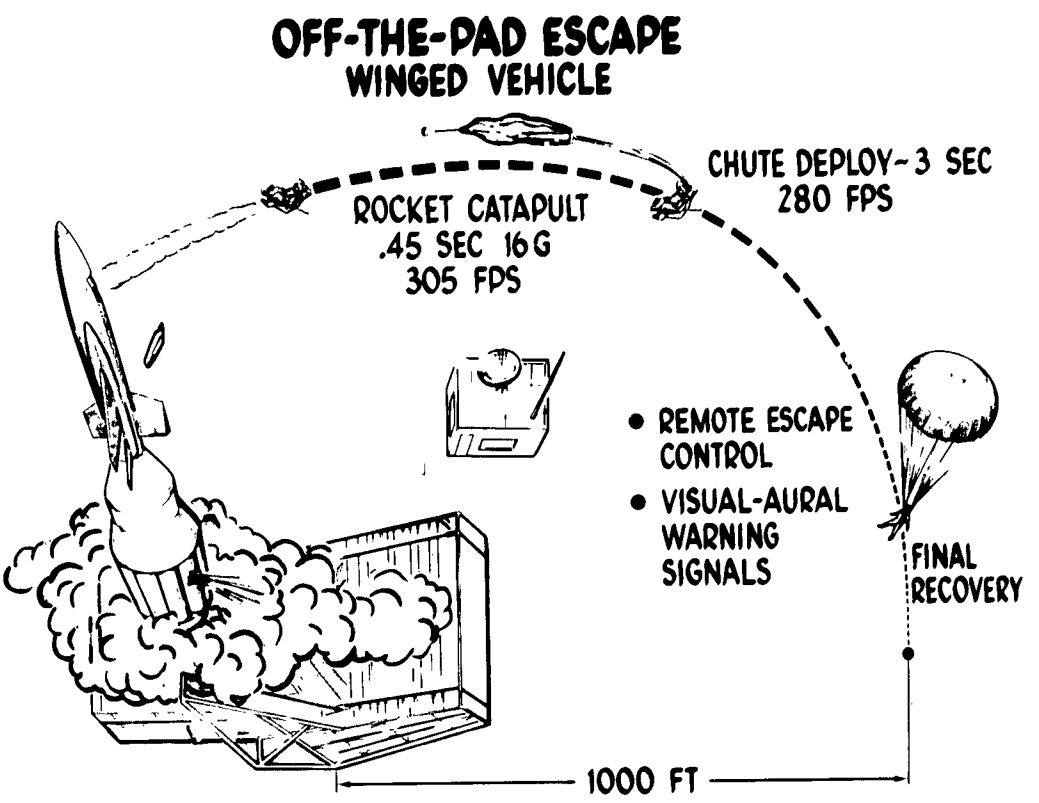


Figure 17

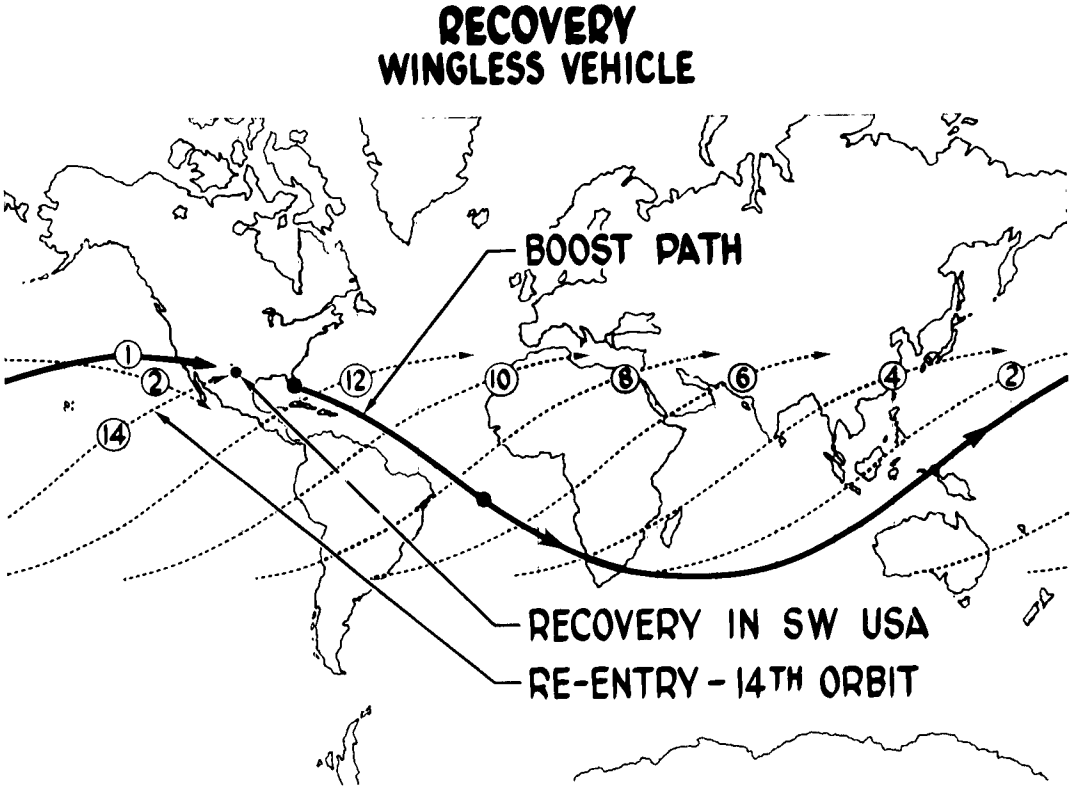


Figure 18

CONCLUSION

No longer is it necessary that the escape and survival system restrict the performance of the aircrew. Indeed, the encapsulated seat provides not only greater mobility and freer vision in normal flight than the pilot has been offered previously, but also permits retreat into a secondary pressure vessel from which the primary air vehicle may be guided to safer altitude when necessary.

The contribution to flight safety of the shedding of encumbering clothing cannot be overemphasized. This capability will inevitably lead to fewer accidents, with a concomitant decrease in loss of personnel and materiel.

Equally important, man becomes an even more efficient element of the man-machine loop. Unrestricted attention to flight duties cannot but enhance mission accomplishment.

These then are the by-products of the new concept in aircrew emergency egress systems. Not to be overlooked is the advance in the art of intra-atmospheric escape itself: the assured safety at ground level and at near-vacuum altitude, at 90 knots and above Mach 3.

REFERENCES

1. Campbell, Col. Paul A., "Escape and Survival During Space Operations", Air University Quarterly Review, Winter 1958-59.

2. Hegenwald, James F., Jr.; Madden, Jerome F.; Penrod, Paul R., "X-15 Research Aircraft Emergency Escape System", Report No. 243 of the Advisory Group for Aeronautical Research and Development, May 1959.

3. Hegenwald, James F., Jr., and Penrod, Paul R., "Aerospace Emergency and Escape Procedures", in Lectures in Aerospace Medicine, School of Aviation Medicine, January 1960.